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ELIMINATION OF ALUMINUM FOIL FOR 81-mm AND 120-mm MORTAR AMMUNITION FIBER CONTAINER

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**ARMAMENT RESEARCH, DEVELOPMENT AND
ENGINEERING CENTER**

Armaments System Integration Center

Picatinny Arsenal, New Jersey

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14. ABSTRACT United Ammunition Container (UAC) in Milan, Tennessee is the current contractor that produces mortar ammunition inner packing fiber containers for the U.S. Army. UAC has not been able to secure any manufacturer that will agree to produce the needed aluminum foil. Apparently, it is not within the commercial standard manufacturing range, which is projected today due to its thickness, temper, and slit width. Not just any material can be used. The U.S. Army Armament Research, Development and Engineering Center's Packaging Division had suggested an alternative commercially available foil, but this is not possible due to the nature of the winding process and the pressures involved. As a result, it was decided that water-vapor permeability study be conducted to compare the moisture protection performance of polyethylene laminated ammunition fiber containers with and without aluminum foil.					
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BACKGROUND

United Ammunition Containers (UAC) in Milan, Tennessee is the current contractor that produces mortar ammunition inner packing fiber containers for the U.S. Army. UAC informed the U.S. Army Armament Research, Development and Engineering Center (ARDEC) Packaging Division, Picatinny Arsenal, New Jersey that the current producer of aluminum foil used to make mortar ammunition packing fiber containers has discontinued producing the foil. After a preliminary evaluation on the fiber container construction, a question was raised whether the aluminum foil significantly increases the moisture prevention capability of the fiber container. It was decided that a water-vapor permeability study be conducted to compare the moisture protection performance of polyethylene laminated (PolyLam) ammunition fiber containers with and without aluminum foil.

The ammunition fiber container design is briefly described as the main body of each container, or the bulk of the tube wall, and is manufactured using ammunition container board per specification A-A-59209. The material is spirally wound under pressure over a steel mandrel machined to the required internal tube dimension forming a hard base board. Next, a layer of PolyLam material constructed of 30 lb natural Kraft/14 lb low density polyethylene (LDPE)/70 lb natural Kraft is layered on the base tube. Another layer of the same Kraft/poly/Kraft material is again layered onto the construction. Finally, there is a layer of black PolyLam material and 30 lb natural Kraft with an exterior layer of 29 lb LDPE laminated to the outside of the tube. The three PolyLam layers are applied with an adhesive that meets or exceeds the requirements of specification A-A-3001. This same technique is used for the construction of the inner neck tube with the exception that it has only one layer of Kraft/poly/Kraft paper on the outside of the tube.

The availability of aluminum foil used in making for the 81 mm and 120-mm fiber tube containers for both PolyLam container and standard asphalt coated container designs has now reached a critical point. UAC stated concerns that the aluminum foil was getting extremely difficult to obtain. The supplier told UAC that they will no longer be producing the foil because of the problems in manufacturing this uncommon military grade product.

UAC also stated that the foil was the major cause of blistering on the containers shipped in hot environmental conditions. UAC is of the opinion that since the aluminum foil is a non-porous material as compared to the fiber material found in the ammunition board and poly paper, there is really no bond created between these layers of material. The adhesive MUST have compatible materials to create a bond. The adhesive will meld into the fibers of the papers and form a bond that is much like welding steel. Upon separation, the layers of fiber material will tare and not separate. When removed from a tube, the majority of the foil is in tact indicating a failed bond between materials. Since there are no pores in the foil for the adhesive to melt into, the layers within the tube construction can be separated with a minimum amount of effort. Thus, the adhesive will break down over time due to age and weather conditions.

Each of the three materials has its own unique shrink and expansion rates when exposed to the elements. Aluminum foil reacts at a rate different from the Kraft paper and from the ammunition construction board. Given these rates and an already inadequate adhesive bond, this will allow for air bubbles to form, thus creating blisters.

The older asphalt containers used hot asphalt layers for adhesive and relied on the high temperatures to help mold the asphalt into every seam, wrinkle, and pore. Too much asphalt caused a buildup of material and blisters, too little asphalt produced non-effective bonds, which also caused blisters.

The PolyLam containers apply cold adhesive in more uniform layers. This results in better adhesion between all layers with the exception again of the aluminum foil. Once the aluminum foil is removed, the containers will have better bonding between layers thus making a stronger container.

In UAC's search for alternate suppliers, they have not been able to secure any manufacturer that will agree to produce the needed aluminum foil. Apparently, it is not within the commercial standard manufacturing range, which is produced today due to its thickness, temper, and slit width. Not just any material can be used, ARDEC's Packaging Division had suggested an alternative commercially available foil, but this is not possible due to the nature of the winding process and the pressures involved. Even the specification material, which UAC has received, does not perform 100% as it should. The alternative foils that UAC has seen so far are of insufficient strength for continuous operation in the winding process. The foil tends to break easily causing a shut down or slow down of the winding process. The foil then needed to be rethreaded through the machinery. This causes a loss of production time and a waste of money due to increase scrap material. Also, the foil at present is keeping the PolyLam containers from being 100% recyclable. Apparently, the foil clogs the screens at the mills and thus they will not take containers manufactured with it.

A decision needs to be made as soon as possible regarding removing the foil as has been asked by UAC in the past. UAC has enough material to last through out the month of December 2006. UAC also has other clients that requested that the foil be removed from their containers for the same reasons stated. Israeli, for example, also purchases this container for their ammunition items and does not use the foil layer as it causes blistering in their shipments.

Since there is no longer an aluminum foil manufacturer for 81 and 120-mm mortar ammunition fiber tubes available, ARDEC's Packaging Division initiated a Request for Deviation (RFD) to avoid cartridge load, assemble, and packaging (LAP) stoppage and production delays.

There are no other packing alternatives at this time. The risk to the user is very low as the fiber tubes are packed into pressure tested (to 3 psig) gasket sealed metal containers. The multi-layered PolyLam material provides ample moisture protection as the tubes will not be exposed to the environment for any extended period of time. The tubes are only removed from the metal containers before firing or when being placed inside a vehicle rack. The rounds are reaching the end of their life cycle at this point.

It is not expected that removing the aluminum foil layers will reduce the water-vapor protection capability of the fiber container. The aluminum foil is NOT a completely water-vapor proof material. There are pin holes in the foil that allow vapor-water to penetrate through. Furthermore, as the aluminum foil is so thin, it can produce wrinkles while being rolled onto the container wall, which further reduces the moisture prevention effectiveness of the material. The low vapor transmission of the foil is compromised by the fact that the foil layer is not in continuous contact with itself, while it is being wound into a container. In fact, none of the layers are in continuous contact. Also, the container has an opened, exposed cardboard face (under the cover tube), which allows each layer of an unsealed container to absorb moisture. At each end, the paper is covered by metal caps, but the ends are not sealed off.

The PolyLam container structure already has outstanding water-vapor protection properties. There is one layer of polyethylene on the exterior of the tube and two layers on the inside of the tube. In-house development tests have shown that the polyethylene is an exceptional water-vapor barrier material.

The ARDEC Packaging Division performed a 60-day water vapor permeability study on fiber containers having PolyLam with foil versus PolyLam without foil. For comparison, asphalt-coated containers were also included in the testing. The purpose of test was to evaluate the effectiveness of aluminum foils for moisture production.

TEST PROCEDURE AND RESULTS

The water vapor permeability study test plan basically followed ASTM D4279-95. The relative humidity level was maintained constantly at 90% for the entire 60 days of the study, which far exceeded the normal storage and operation conditions. For the 120-mm mortar ammunition: 24 asphalt containers with foil, 24 PolyLam containers with foil, and 24 PolyLam containers without foil were tested. For the 81-mm mortar ammunition: 36 PolyLam containers with foil and 36 PolyLam containers without foil were tested. We selected a minimum of 24 containers for each sample to obtain statically significant data as required by the Quality Assurance Office. In total, 144 containers were tested.

Each container had a hole drilled in the cover to allow for an AGM Container Control Inc. (P/N TA476-2522) desiccant holder to be installed using a gasket seal to the metal end plate. The holder has an access port with removable cap to allow for desiccant sampling without the need to disturb the taped container seal. Activated desiccant (two unit bag of Silica Gel) was placed in each holder. The procedure used to collect data was as follows: Containers were removed from the humidity chamber and lined up in number order. The holder cap was opened and the desiccant bag removed. The cap was replaced while the desiccant was weighted and data recorded. The cap was then opened, the desiccant replaced, and cap secured. The scale was zeroed and balanced after every five measurements. Figure 1 shows the set up structure of desiccant holder and fiber container. Figures 2 through 5 show the testing equipment.

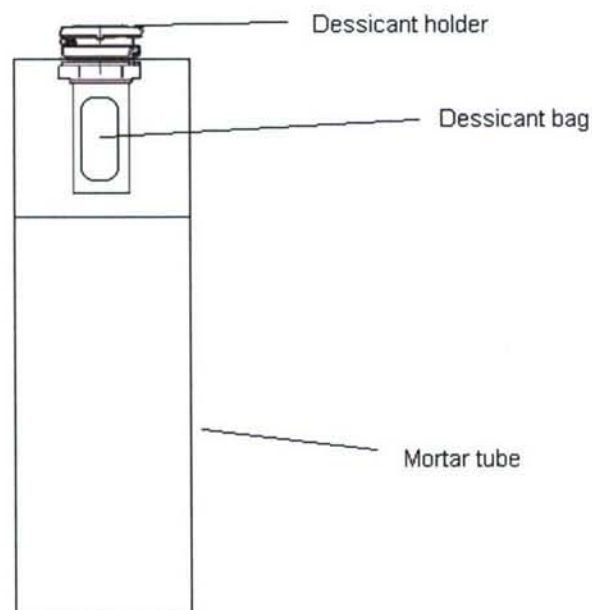


Figure 1
Set up structure



Figure 2
Environmental chamber



Figure 3
Technicians are taking the containers out of chamber

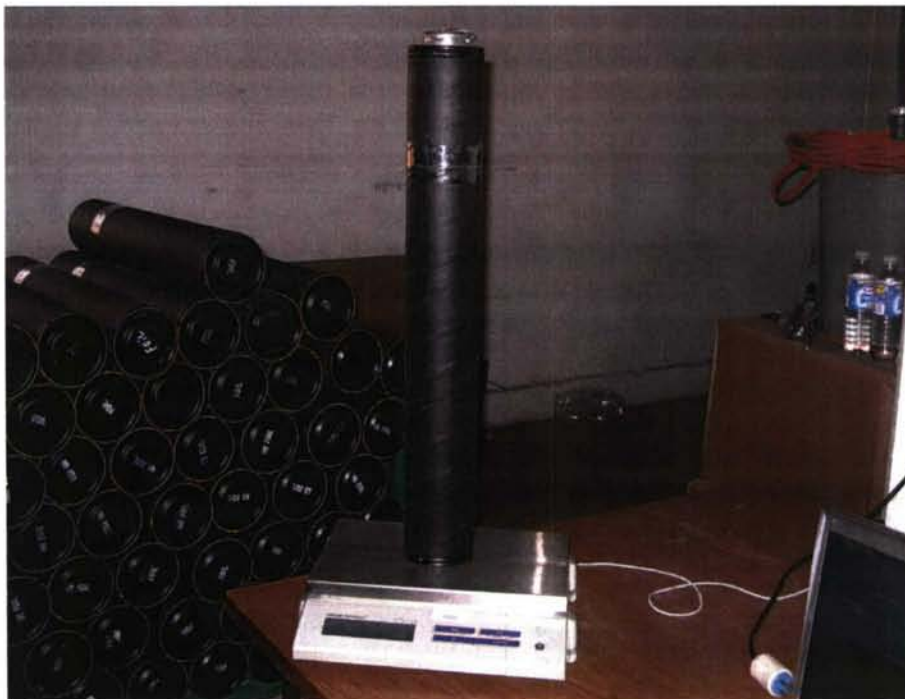


Figure 4
Container measurement



Figure 5
Desiccant bag measurements

DETAILED TESTING PROCEDURES

Apparatus

Desiccant

A desiccant shall be used that has a powerful affinity for water and a high drying efficiency, that is, a low vapor pressure after absorbing a large amount of water. The desiccant shall be in the form of small lumps that will pass a no. 8 (2.36-mm) sieve and be free from fines that will pass a no. 30 (600- μ m) sieve. Anhydrous calcium chloride and anhydrous magnesium perchlorate were found suitable. When the test is made to determine the suitability of a specific container for a particular product, that product may be used inside the test specimen instead of the desiccant, in which case the specimen shall be filled to normal capacity.

Weighing Balance

A weighing balance accurate to within 1 g shall be used. When the required amount of desiccant is greater than can be weighed on a balance of this sensitivity, two or more receptacles shall be used and weighed individually. When product tests are made, a regular laboratory balance and drying oven or other appropriate equipment are required for making standard moisture determinations peculiar to the product.

Receptacle for Desiccant

A no moisture-absorptive receptacle 0.75 to 1.5 in. (19 to 38 mm) deep shall be used for holding the desiccant within the container being tested. It should be equipped with a cover that will rest on the top rim of the receptacle to protect the desiccant from picking up moisture while being weighed. The size of the weighing receptacle or receptacles shall be such that the exposed area of desiccant is not less than 10% of the area of the test specimen. For testing large containers, this may require using two or more weighing receptacles.

Test Chamber

A test room or cabinet provided with conditioned air that is continuously circulated around the specimens under test. The conditions in the chamber shall be such that no condensation occurs on the specimens except during that portion of the cycle when the exposure is changed from a low temperature to a high temperature.

Test Specimens

Test specimens shall be representative of the containers being tested, and shall be closed and sealed in the required manner.

The performance shall be based on tests of not less than two representative specimens of a given size and type of container.

Procedure

Locate the weighing receptacle or receptacles centrally within the test specimen, using a non-absorptive support when required. Place the selected quantity of the desiccant in the receptacle sufficient to uniformly cover the area of the receptacle to a depth of not less than 1/2 in. (13 mm). Cover, and after weighing, immediately transfer into the test specimen. Uncover the receptacle and close and seal the specimen in the required manner. The desiccant may require one or more replacements if it becomes noticeably moist during the test.

Place the specimen inside the test room or cabinet in a position where free access of the conditioned circulating air is provided on all surfaces of the container according to the following:

Constant Atmosphere Method

Normally surrounding conditions are 90 ± 2 % relative humidity and a temperature of $100^\circ \pm 2^\circ\text{F}$ ($37.7^\circ \pm 1.1^\circ\text{C}$).

Constant Method

Accuracy of the test is adversely affected by too frequent weighings. For highly permeable containers a minimum weighing frequency of 3 days is recommended. For containers having a low rate of transmission, a weighing frequency of biweekly to monthly is recommended.

Note that the MIL-STD-810 test method was not used because ASTM D4279-95 is a more extreme test from relative humidity's perspective. For instance, MIL-STD-810 testing requirement is 10 days where D4279-95 requires a 60 day period for testing. The minimum number of 24-hr cycles for the test is 10 days, which has historically proven adequate to reveal potential effects in most material. Extending the test as specified in the test plan will provide a higher degree of confidence in the material that it can withstand warm, humid conditions.

Figures 6 through 10 show the various containers and their performance.

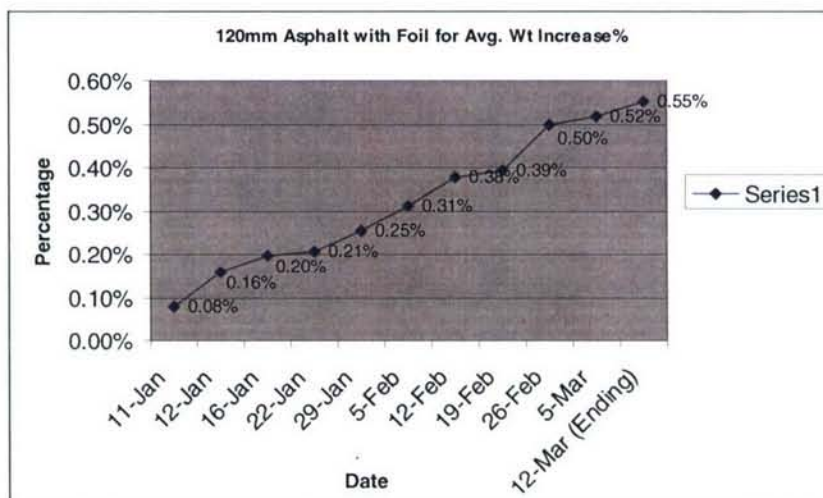


Figure 6
120-mm asphalt with foil

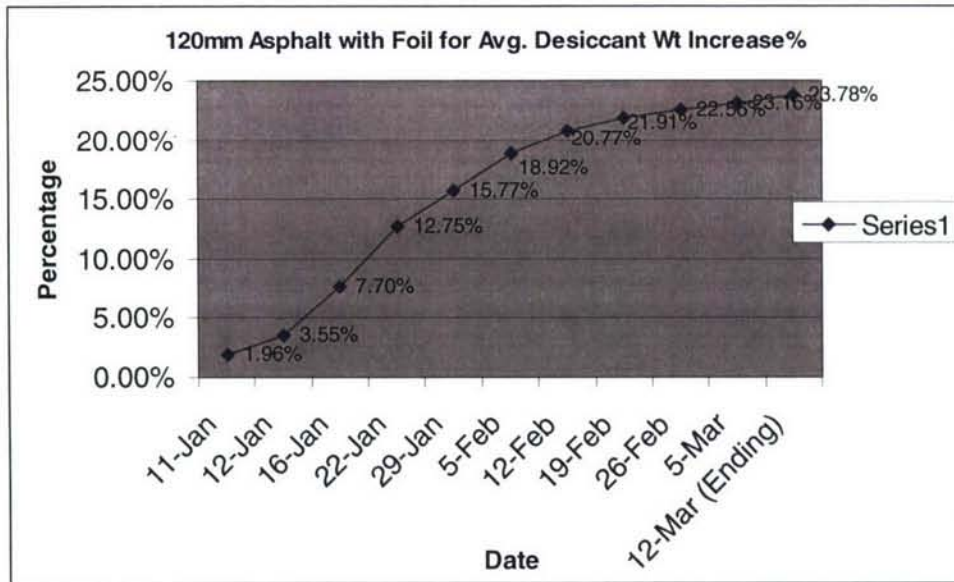


Figure 6
(continued)

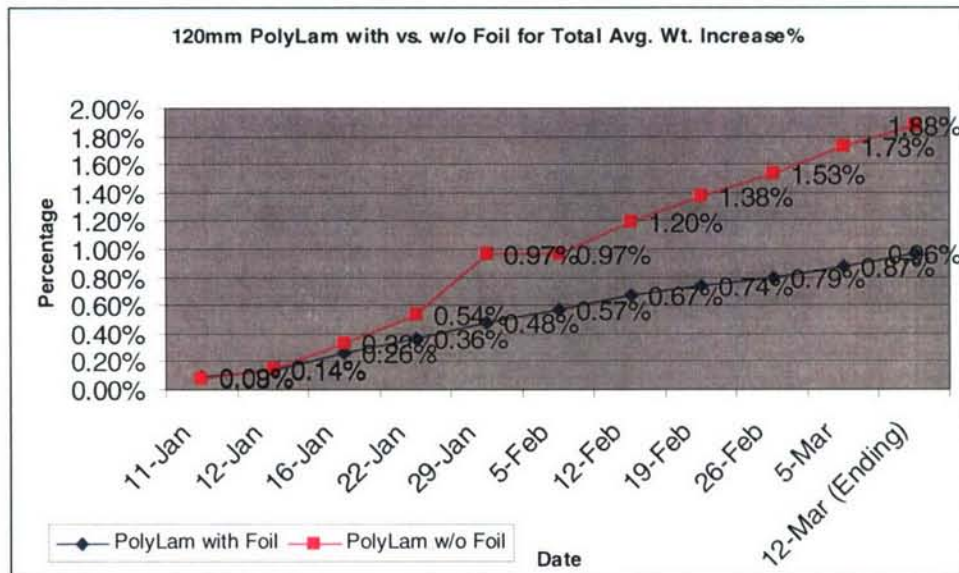


Figure 7
Combination of 120-mm PolyLam container with versus without foil for total average weight increase percentage

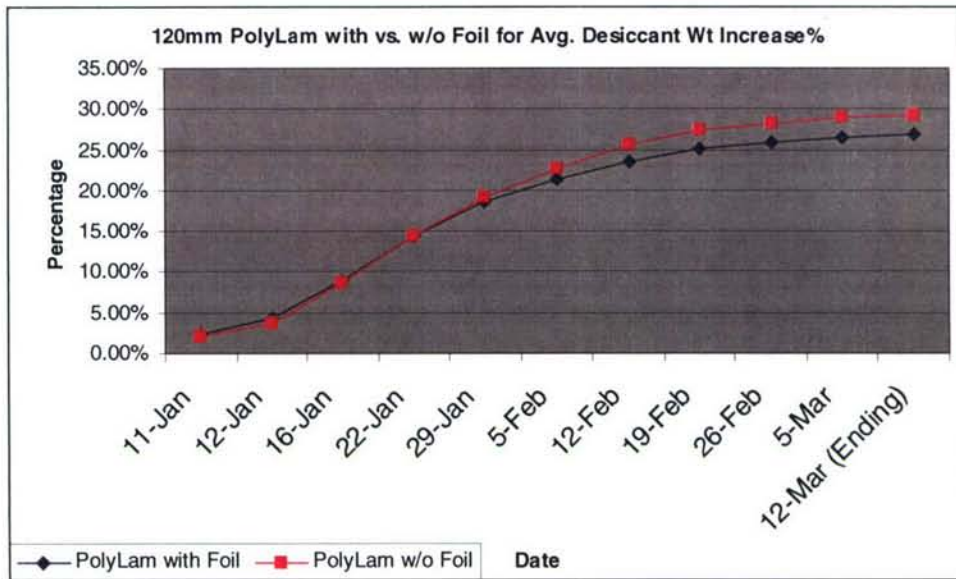


Figure 8
Combination of 120-mm PolyLam container with versus without foil for average desiccant weight increase percentage

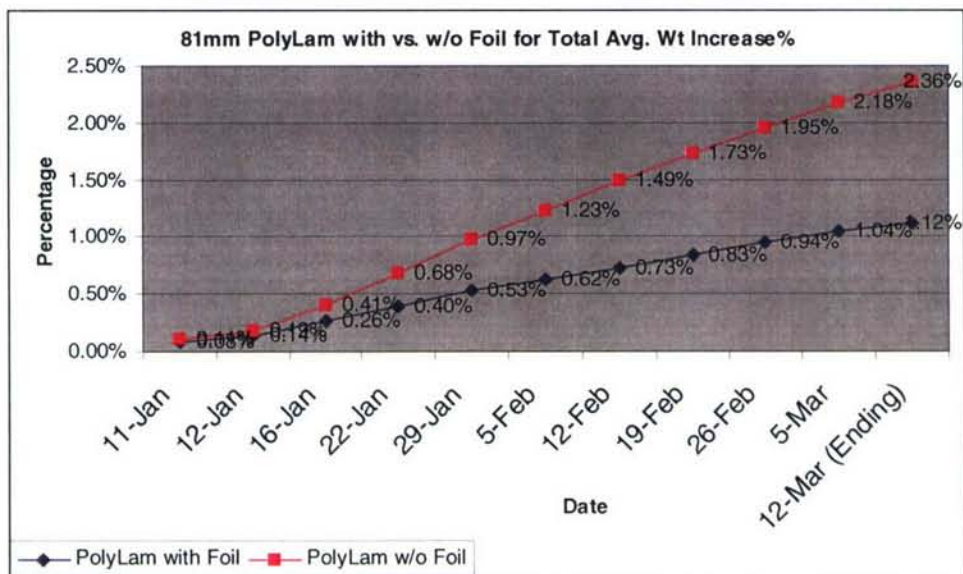


Figure 9
Combination of 81-mm PolyLam container with versus without foil for total average weight increase percentage

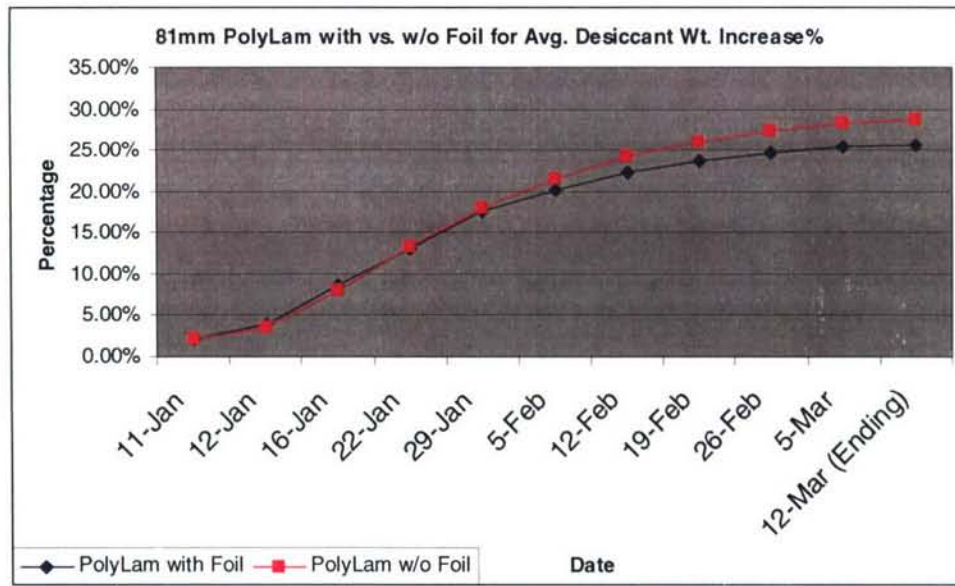


Figure 10

Combination of 81-mm PolyLam container with versus without foil for average desiccant weight increase percentage

The average weight gain of **desiccant** inside the fiber containers after 6 days of extreme humidity testing is summarized as follows (7 days mark is on weekend):

- 120 mm: PolyLam containers without foil gained 8.73%, while the containers with foil gained 8.94%. Thus, the container with foil gained 0.21% more in weight than without foil.
- 120 mm: Asphalt containers with foil gained 7.70%. There were no asphalt containers without foil tested. The asphalt container is no longer used for mortar ammunition and was tested for information only.
- 81-mm: PolyLam containers without foil gained 8.11%, while the containers with foil gained 8.53%. Thus, the container with foil gained 0.42% more in weight than without foil.

Note that at 6 days, the containers that have foil gained more moisture than those without foil. This variation in data is not significant and basically means that both containers are performing equally at the 6 day point. The comparison graph (table 1) shows that as the test moves forward, the containers without foil ultimately gain more moisture than containers with foil.

Table 1
Comparison graph

	120-mm PolyLam w/o foil	120-mm PolyLam with foil	Difference
6 days	8.73%	8.94%	0.21%
	120-mm asphalt w/o foil	120-mm asphalt with foil	Difference
6 days	n/a	7.70%	n/a
	81-mm PolyLam w/o foil	120-mm PolyLam with foil	Difference
6 days	8.11%	8.53%	0.42%

The average weight gain of desiccant inside the fiber containers after 60 days (table 2) of extreme humidity testing is summarized as follows (60 days testing was an engineering evaluation at extreme condition. The fiber container was designed as an inner packing container, which would not be exposed to such adverse operation condition in its life cycle):

- 120 mm: PolyLam containers without foil gained 29.19%, while the containers with foil gained 26.87%. Thus, the container without foil gained 2.32% more in weight than with foil.
- 120 mm: Asphalt containers with foil gained 23.78%. There were no asphalt containers without foil tested. The asphalt container is no longer used for mortar ammunition and was tested for information only.
- 81 mm: PolyLam containers without foil gained 28.77%, while the containers with foil gained 25.59%. Thus, the difference between the two is that the container without foil gained 3.18% more in weight than with foil.

Table 2
60 days of extreme testing

	120-mm PolyLam w/o foil	120-mm PolyLam with foil	Difference
60 days	29.19%	26.87%	2.32%
	120-mm Asphalt w/o foil	120-mm Asphalt with foil	Difference
60 days	n/a	23.78%	n/a
	81-mm PolyLam w/o foil	120-mm PolyLam with foil	Difference
60 days	28.77%	25.59%	3.18%

As can be seen from the results, there is a very small difference of desiccant weight gain between containers with and without foil. It must also be noted that the moisture gain within the first 7 days of testing (i.e., the expected life of the loaded tube outside the gasket sealed metal container) was negligible.

The test data also proves that the aluminum foil used in making the containers is not a total water-vapor proof barrier material. Although asphalt containers had lowest moisture gain, Asphalt material is no longer used because of three reasons. First, it is bad for the environment. Second, it slows down the manufacturing process. Third, asphalt material tends to melt in high temperature environments. Once the asphalt material melts it becomes sticky and the marking on container will start to deteriorate. The melted asphalt is messy and hard for the user to handle.

CONCLUSIONS

Based on the test results, it is concluded that the aluminum foil does not improve the moisture protection ability of the fiber ammunition container in an effective manner.

RECOMMENDATIONS

The U.S. Army Armament Research, Development and Engineering Center's (ARDEC) Packaging Division recommends and supports the removal of the foil material from the mortar fiber container because it will not improve the moisture protection provided to the mortar rounds. Also, there is a cost savings by removing the aluminum layer from 81 and 120-mm mortar ammunition fiber containers listed:

81 mm = \$0.1276 saving per container

120 mm = \$0.1848 saving per container

ARDEC's Packaging Division also recommends the aluminum foil-less PolyLam covered fiber tube be used to support ongoing contracts once the foil is no longer available. An Engineer Change Proposal to implement the design change into the Technical Data Package will be processed.

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